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Thin film coatings for solar and thermal radiation control prepared by physical vapour deposition

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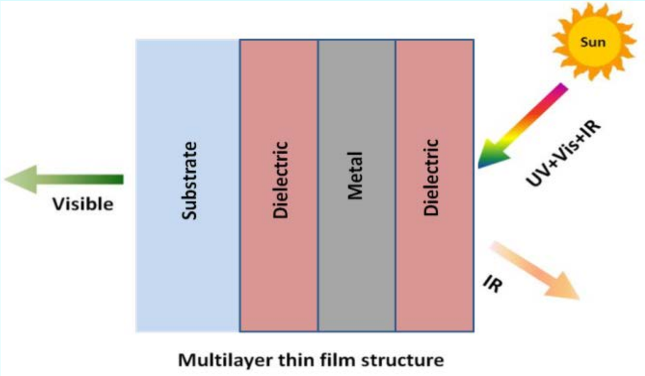
OUTLINE

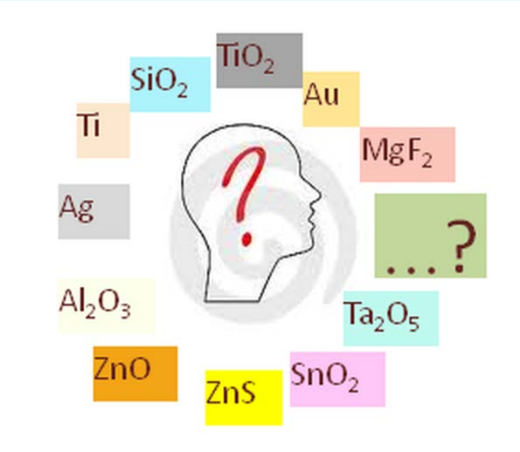
- **Introduction to energy-saving glazings**
  - Metal-dielectric thin film coatings
  - Materials science of metal-dielectric thin-film systems
  - Solar control glazings: aims and challenges
- **Physical Vapour Deposition (PVD) of metal-dielectric systems**
  - Material properties and layer intercompatibility
  - Deposition methods and characterisation procedures
  - Manufacturability of designs optimized theoretically
- **Experimental development and characterization results**
  - Multilayer thin film structures – manufacture and properties
  - Main results achieved
- **Conclusions**

INTRODUCTION

- **Energy saving glazings and optical coatings:**



  - Multilayer films on glass and radiation control
  - Cooling- and heating-related electricity savings
  - Solar control and low emissivity combination suits most climates

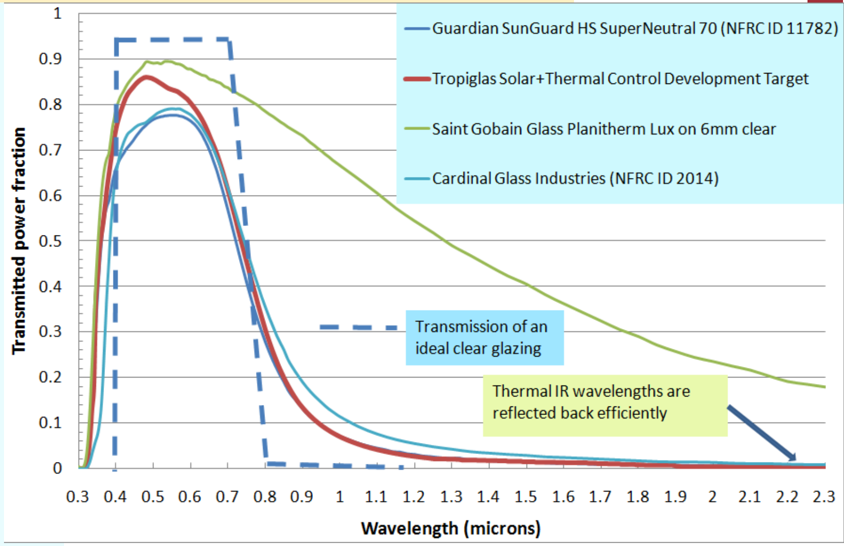


- **Enabling technologies and materials:**
  - Solar IR control through reflecting it back out
  - Thermal insulation improvements (Low-E glass)
  - Material combinations: TiO_2/Ag/TiO_2, WO_3/Ag/WO_3 etc.
  - New research is required to achieve better coating durability, higher visible transmission and spectral selectivity

Aims and challenges

Aims: to demonstrate advanced coatings on glass substrates which

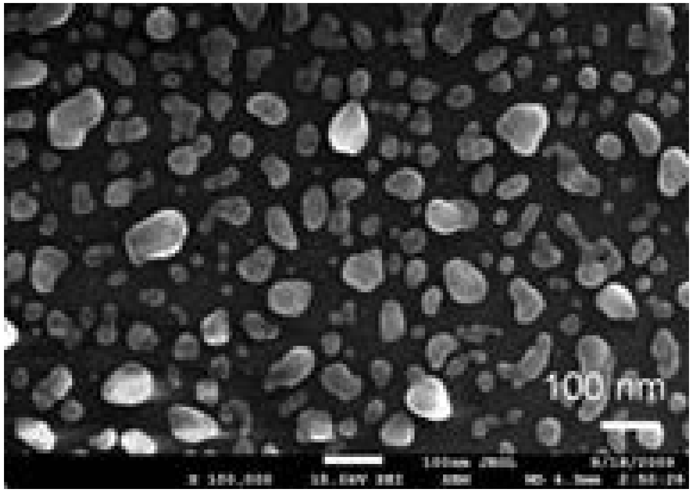
- Block (selectively) most of the UV, solar IR (0.75-2.3μm) and thermal (2.5-40μm) radiations.
- Achieve high transmission (>80%) in the visible range.



Materials science of metal-dielectric systems:

- Selection of appropriate materials - n(λ), k(λ)
- Ensuring optimum growth mode in ultrathin layers
- Preventing chemical reactivity
- Design of nanocomposite materials

  (or cross-contamination prevention)



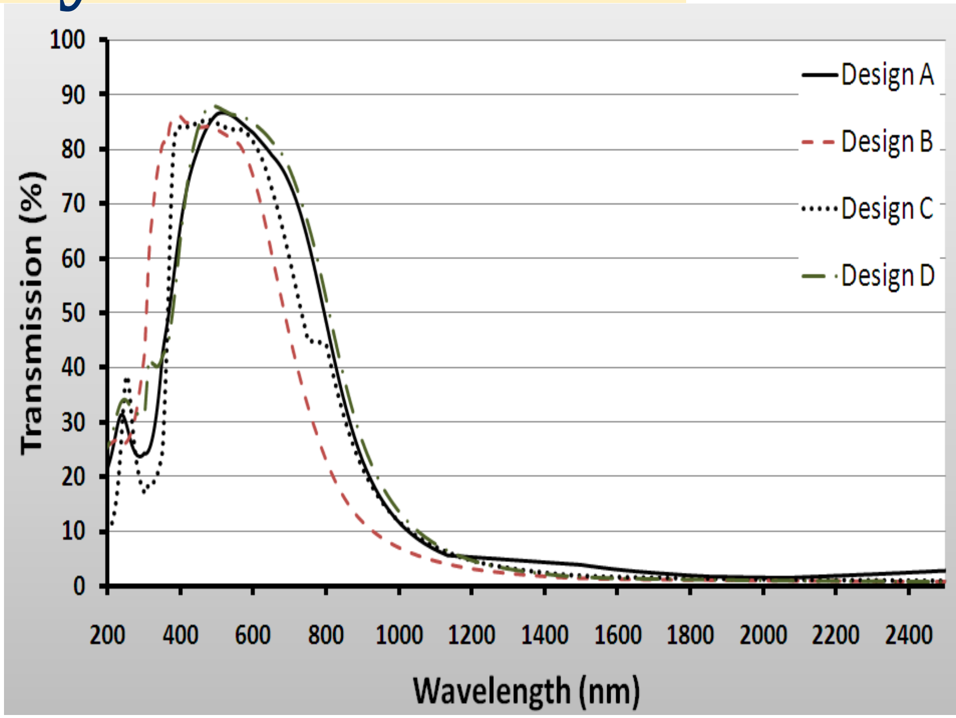
Ultrathin metal layers can have different morphologies

Optimisation of metal-dielectric multilayers

- Optilayer 8.85 software used
  - **Dielectrics**
    - Oxides, nitrides sulfides and fluorides of refractive index from 1.38-2.4
    - Materials had high transparency across the entire visible range
  - **Metal layers** (Ag)
- **Structures:**

Glass/$D_{(adh.)}$/D_1..D_n/Ag/D_k..D_l/Ag/D_x..$D_{y(cover)}$

Single-Ag and triple-Ag designs were also trialled



Simulated spectral transmittance curves for different metal-dielectric multilayer thin film structures.

Coating production capabilities and deposition techniques

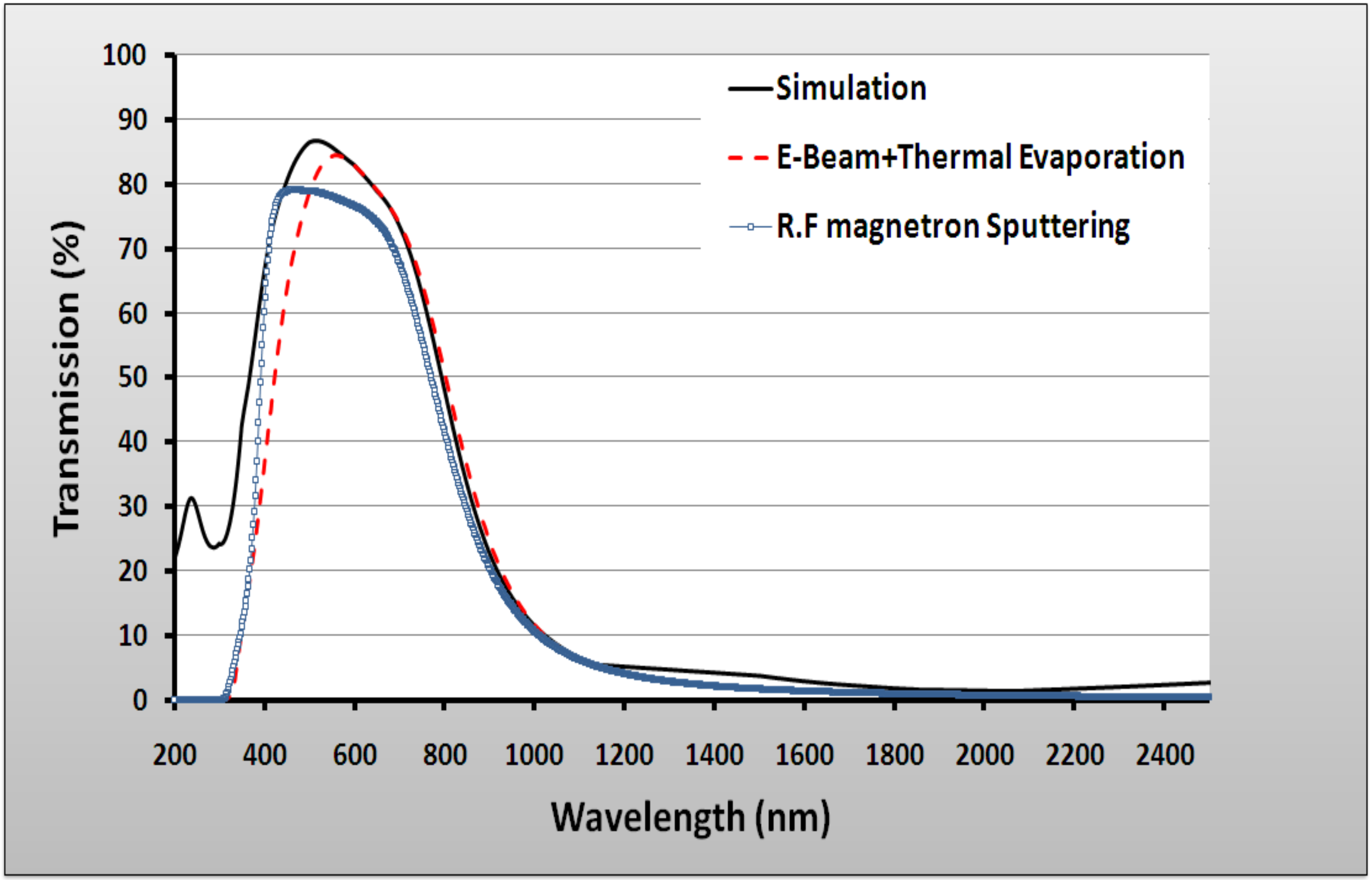
E-Beam and thermal evaporation

RF magnetron sputtering

Typical deposition conditions

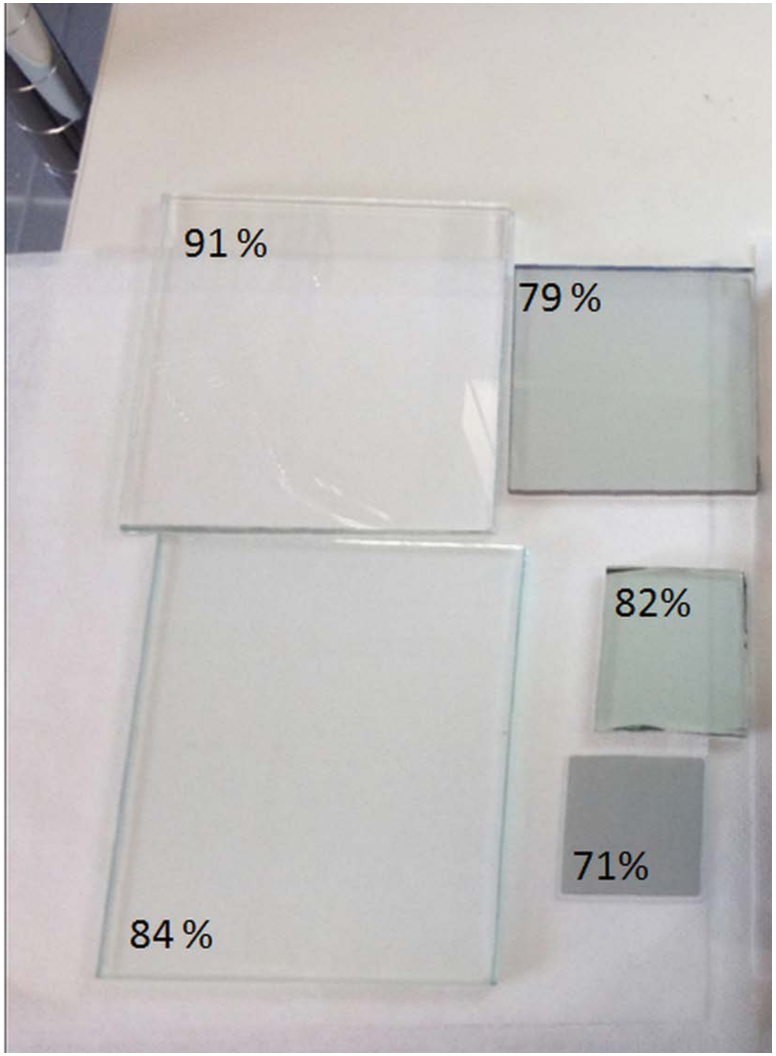
- Glass substrates were not heated (at 20ºC).
- Base vacuum pressures achieved in both deposition chambers were near 10^{-6} Torr.
- Layer growth rates were typically between 0.5-2.5 Å/s
- Ag layers were either sputtered or evaporated thermally
- Non-metallic layers were all E-Beam evaporated
- The argon (Ar) partial pressure used in RF sputtering chamber was between 1-2 mTorr.
- No O_2 input used – selected oxides with minimim O_2 loss

Experimental results – sputtered and evaporated metal-dielectric coatings on glass

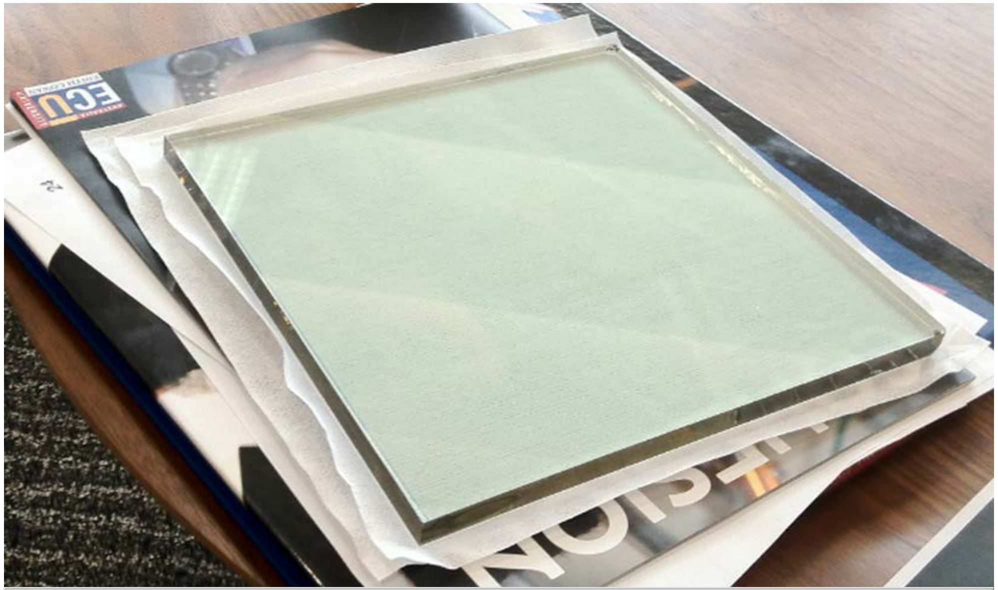


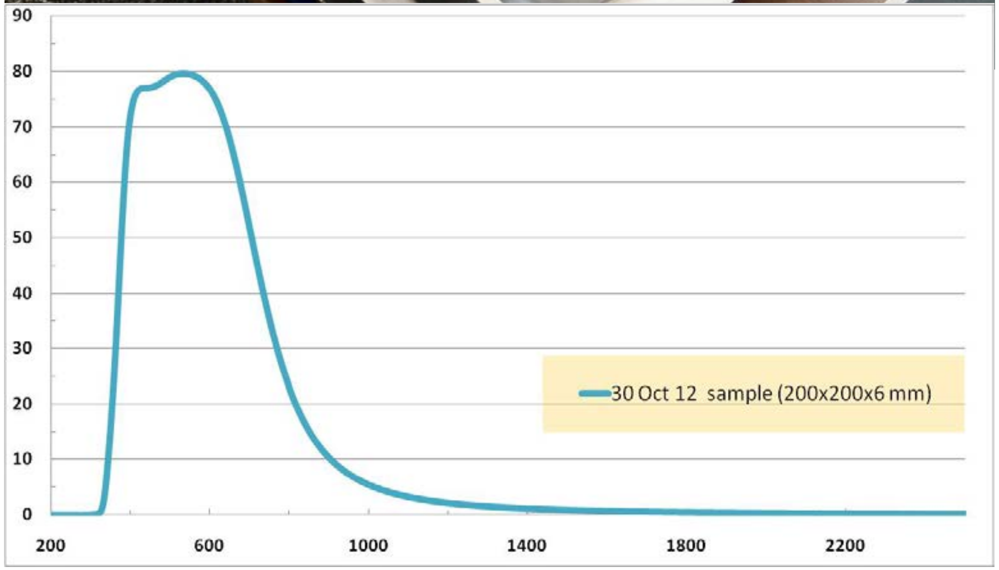
Simulated and measured spectral transmittance curves for the optimized multilayer thin films

Experimental results – sputtered and evaporated metal-dielectric coatings on glass



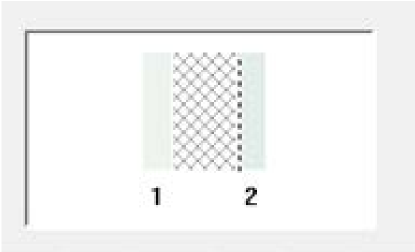
Ultraclear/Clear glass substrates (left) and sputtered coatings on glass (right)



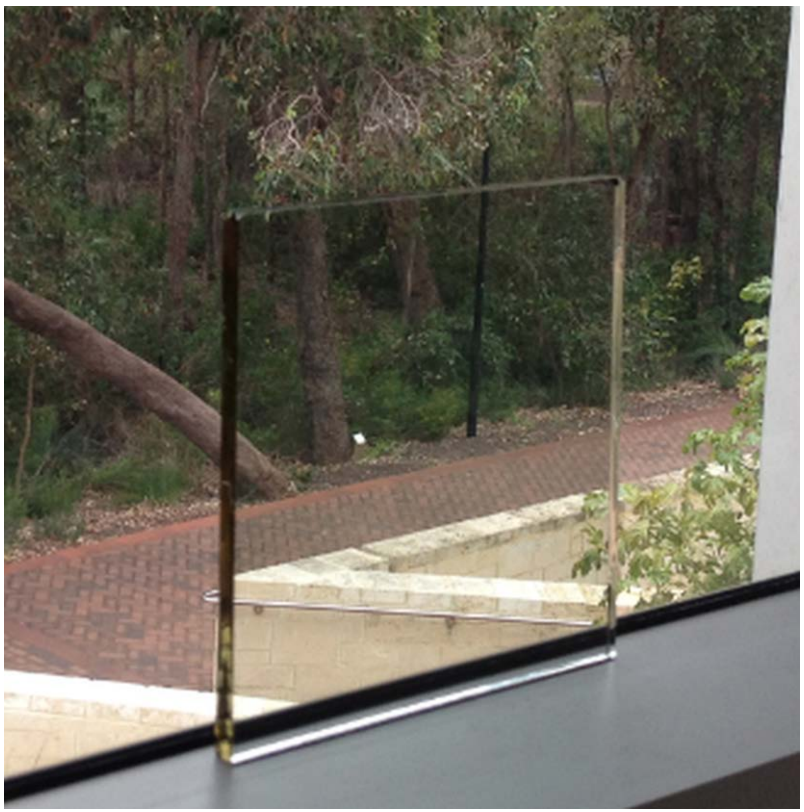


Evaporated coating on glass (200x200 mm)

Evaporated large-area, stable metal-dielectric coatings for advanced glazing systems



http://windows.lbl.gov/software/window/window.html



Evaporated coating on glass (200x200 mm)

Glazing performance calculations performed using LBNL's **WINDOW 6.3** software resulted in the following data set:

Center of Glass Results | Temperature Data | Optical Data | Angular Data | Color Properties

Ufactor	SC	SHGC	Rel. Ht. Gain	Tvis	Keff	Gap 1 Keff
W/m2-K			W/m2		W/m-K	W/m-K
1.639	0.528	0.460	345	0.729	0.0300	0.0300

Main double-pane glazing parameters are

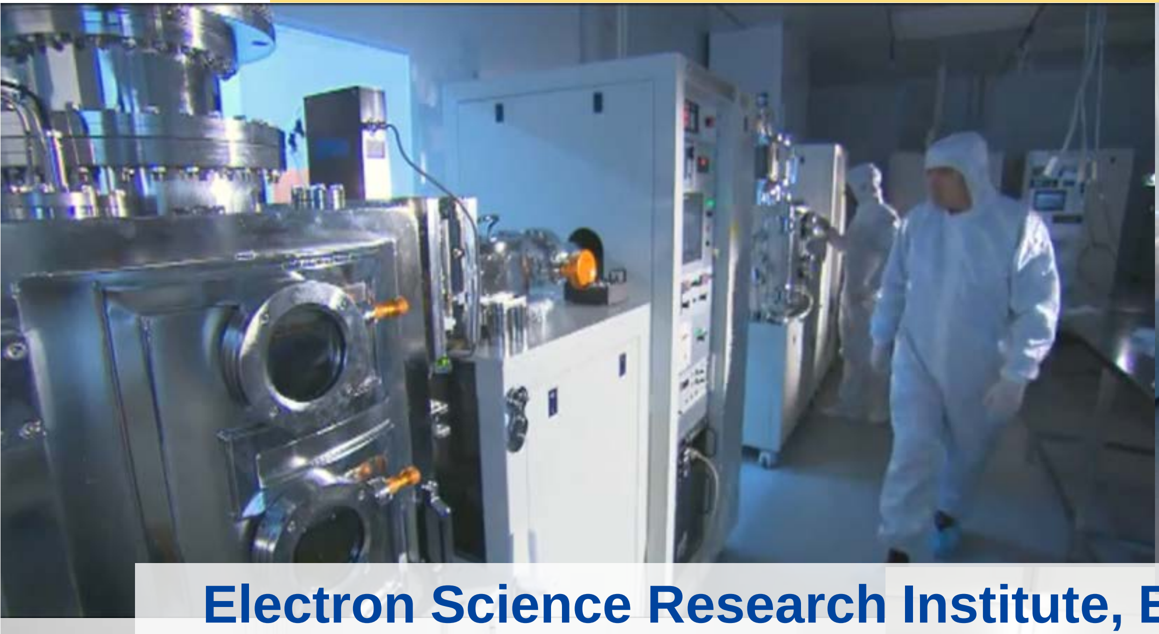
- Solar Heat Gain Coefficient (SHGC) = 0.46
- Visible Transmission VT = 72.9 %
- Relative Heat gain = 345 W/m^2
- Thermal insulation U-factor = 1.639 W/(m^2*K)

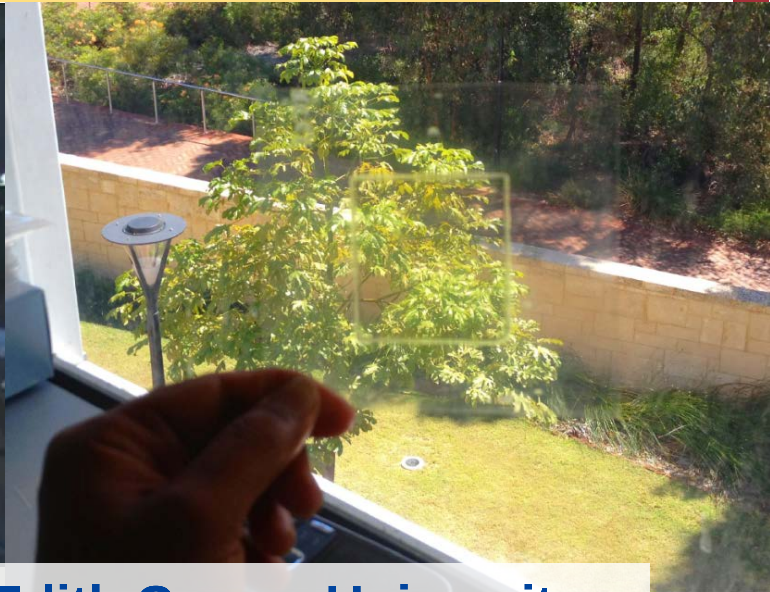
In an insulated glass unit, when used as an intermediate coating, <u>a very attractive combination of multiple energy-saving performance parameters results</u>

CONCLUSIONS

- Thin film coatings suitable for solar+thermal radiation control were studied experimentally
- E-Beam, Thermal Evaporation and RF sputtering processes optimised for spectrally-selective metal-dielectric systems
- PVD parameters optimised for high quality thin films production, including the control over ultrathin layer properties
- Transparent and stable heat-mirrors designed and fabricated

Thank you





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